Wolf Harvest Model Simulations for 2010 Quota Discussions

— Informational Supplement —

Overview

FWP and the FWP Commission develop and approve wolf hunting and trapping seasons, respectively, as a two-step process. First, the basic components and structure of the season (such as season dates, management units, means of take etc.) are determined. These are the rules and regulations that outline what's legal and what is not with respect to licensed public harvest. Second, the actual number of wolves that could be harvested statewide and within each wolf management unit (WMU) is determined.

The FWP Commission has previously approved management of wolf harvest through a quota system in which the number of wolves that could be harvested is pre-determined before the season opens. When the prescribed level of harvest in each WMU is achieved, the season closes in that unit upon 24-hour notice. Eventually all units close upon reaching the prescribed level of harvest (i.e. the approved quota in that unit) or the season closing date, whichever occurs sooner.

The FWP Commission approved a wolf hunting season in February 2008 for the fall 2008 and 2009 seasons. The 2008 season was precluded by litigation. The 2009 season, however, was not. The 2009 season transpired based on regulations and a statewide harvest quota of 75 spread across 3 large WMUs, as approved by the FWP Commission. The 2009 quota setting decision process was informed by results of a model that simulated harvest and made predictions about the status of the wolf population at the end of the year. A biologically conservative total quota was selected in an effort to gain experience, while recognizing biological uncertainty.

The 2010 season structure proposal and proposed 2010 quotas are informed by the actual outcomes and results of the 2009 wolf hunting season. In addition, FWP's quota proposal is also informed by FWP regional input and local objectives, as well as results of the same harvest simulation model using contemporary 2009 wolf population data. This document describes the modeling approach itself and provides some examples of predicted outcomes [total wolves in the population and number of Breeding Pairs (BP)] for several different hypothetical harvest quota scenarios. The model inputs are based on 2009 wolf population data collected in the field throughout the year and reported as minimum observed counts in the annual report (Sime et al. 2010). This document will supplement the FWP Wolf Hunting Season / Quota Change Justification for a 2010 season and 2010 quota proposal.

Introduction to the Purpose of Modeling

In order to consider potential quota levels, FWP explored a wide variety of alternatives and potential outcomes. By analyzing existing data sets and making some assumptions, FWP developed a wolf harvest model simulation to consider a range of harvest rates and the potential effects on the wolf population and the number of BPs at the end of the year of harvest (December 31, 2010, in this case). This effort determines sideboards around what could be appropriate harvest levels that would not jeopardize the population or cause it to drop below 15 BPs. It allows FWP and the FWP Commission to assess "risk" that the wolf population would fall to unacceptable levels. Montana is required to maintain at least 10 BPs and 100 wolves as its contribution to a recovered northern Rockies wolf population, but the U.S. Fish and Wildlife Service would initiate a northern Rockies status review if the Montana (or Idaho) population fell below 15 BPs or 150 wolves for three

consecutive years. At the statewide level, least 15 BPs are required to offer any public hunting opportunities and to use lethal control to address wolf-livestock conflicts.

Managing for higher wolf numbers affords a greater degree of flexibility when addressing wolf-livestock conflicts, allows for higher levels of public harvest opportunity, and buffers any unexpected environmental events such as weather-induced prey declines or disease / parasites in the wolf population without jeopardizing population viability and species recovery. Harvest needs to be implemented in such a way that accounts for the dynamic aspects of conflict management and wolf population ecology. Nonetheless, regulated harvest is also appropriately viewed as the primary mechanism to manage the wolf population at both local and statewide scales in a proactive way, similar to the management of other resident wildlife species. FWP seeks to regulate wolf harvest at a biologically sustainable level.

FWP monitors the wolf population on an ongoing basis throughout the year through a combination of radio telemetry, public wolf reports, track surveys, etc. At the end of the calendar year, FWP reports the minimum number of BPs, individual packs, and total wolves. This can be thought of as minimum observed and known by FWP to be alive and in the population on the last day of each calendar year. The "true" total population number is higher, but like other managed wildlife species in Montana, the exact number of animals in a population is unknown. For wolves, preliminary results of research being conducted by the University of Montana suggest that FWP's minimum counts could be 10-30% below the total estimated using a more sophisticated approach than just minimum observed counts obtained in the field. Even though wolves are monitored on a year-long basis, on December 31 of each calendar year, a "snapshot" of the minimum number of wolves, packs and BPs is taken. These year-end counts are the basis for and how FWP demonstrates maintenance of a recovered population. They are also used to establish future adaptive management direction and harvest opportunity the following year.

Ultimately, the purpose of the harvest simulation modeling effort is to inform the harvest regulatory decisions by allowing FWP and the Commission to compare and contrast predictions of total wolf numbers (which includes lone dispersing animals that may be subject to harvest) and total BPs resulting from various combinations of harvest quotas across individual WMUs. This further contributes to the decision process by allowing FWP and the Commission to assess "risk" that a certain combination of harvest quotas would cause the wolf population to decline below 15 BPs statewide. Finally, the model exercise allows FWP to make a broad, cursory comparison between what the model predicted for the December 31 total population estimate and what FWP's field monitoring data suggest is a minimum observed estimate. This comparison allows FWP an opportunity to refine its modeling approach and to gauge the degree of conservatism likely inherent in FWP's minimum observed counts.

The Harvest Model Itself

FWP explored the predicted outcomes of the proposed 2010 quota-based wolf hunting season by simulating various harvest rates in each of the three 2009 wolf management units. The simulations were intended to gauge the near-term response of the Montana wolf population to harvest. A four-step process was used.

The primary goals were to:
- Examine various combinations of harvest rates to determine population sensitivity by adding harvest mortality to existing causes of death for each of the three 2009 management units

and statewide, given the level and patterns observed in the 2008 – 2009 population field data.

- Gauge the risk of the statewide number of BPs (the federal recovery definition) dropping below 15 in the year of hunting implementation.
- Consider various combinations of harvest rates that result in a predicted wolf population increase, population stability, or a population decrease.
- Predict the number the number of BPs and the minimum total number of wolves in each of the three 2009 WMUs and statewide (to include lone dispersing animals) at the end of the year of harvest, December 31, 2010 in this case.

1. Determine Population Baselines

The Montana wolf population has increased from a minimum of 66 wolves (6 BPs) in 1995 to a minimum known of 524 (37 BPs) as of December 31, 2009. Trends are apparent at the 2009 WMU level (Figure 1). But in order to simulate the effects of harvest, a general baseline understanding of wolf population dynamics is the required first step. Rates of birth, death, immigration and emigration are calculated using actual field data. Those data are used to create a model that was largely based on and representative of the biological features of wolves and environmental factors in each of the three management units (Mitchell et al. 2008). There are true biological and environmental differences between each of the three 2009 units, which help explain observed differences in trends and mortality levels in each of the units (See Figures 1 and 2; Mitchell et al. 2008, Smith et al. 2010). The model incorporated birth, death, immigration, and emigration for each unit using actual data from 2008 and 2009. Several assumptions about wolf population dynamics were necessary. Each assumption is likely to be violated to one degree or another, but this uncertainty can't be easily quantified nor avoided. The assumptions were:

- Rates of birth, death, immigration, and emigration are known with certainty, constant and equal to those observed in each area in the previous year.
- Mortality rates are constant for individual wolves.
- Immigration results in the formation of new packs of a consistent age structure and at a constant rate within each area.
- Reproduction results in a consistent number of pups and only in packs that existed in the previous year in each area.
- FWP does not have an accurate way to estimate the number of lone / dispersing wolves. However, according to the peer reviewed literature, about 10% of the wolf population is comprised of single wolves not associated with a pack. Therefore, FWP's minimum known population of "pack-living" wolves is determined initially through field observation and then mathematically increased by 10% in each unit.
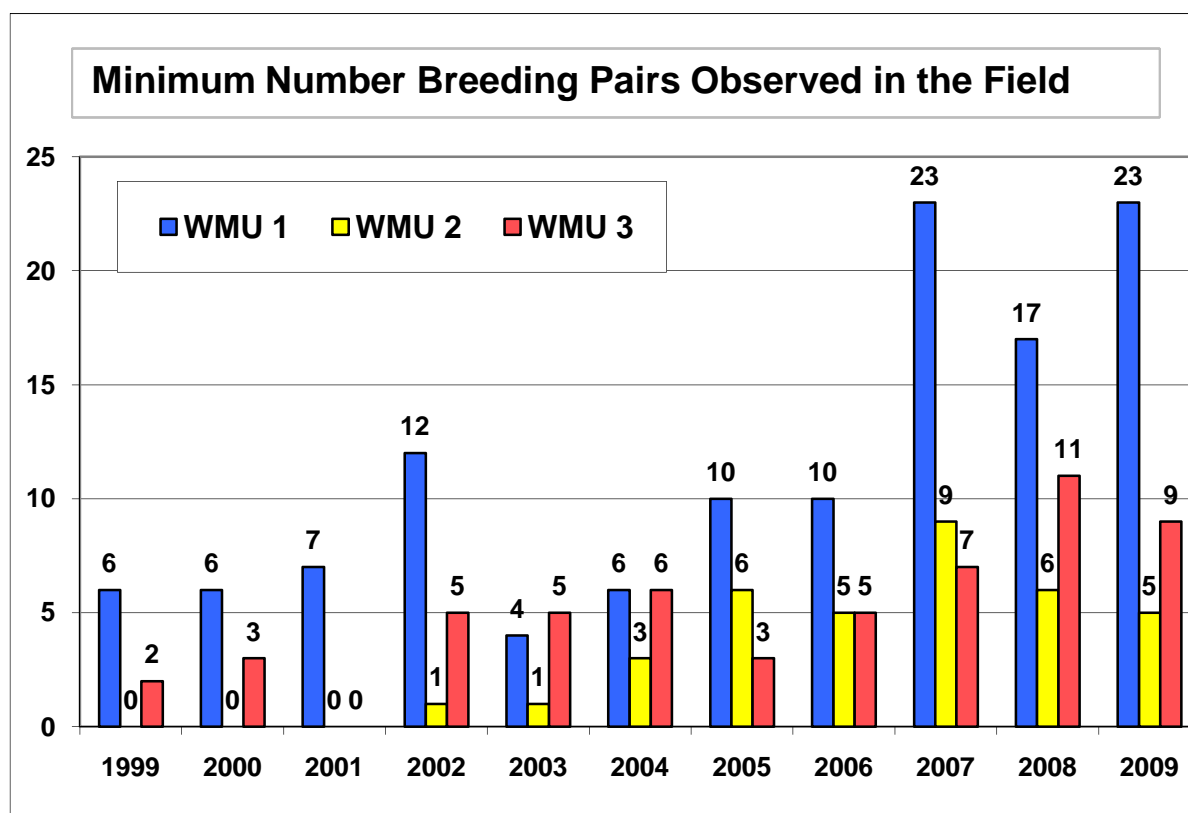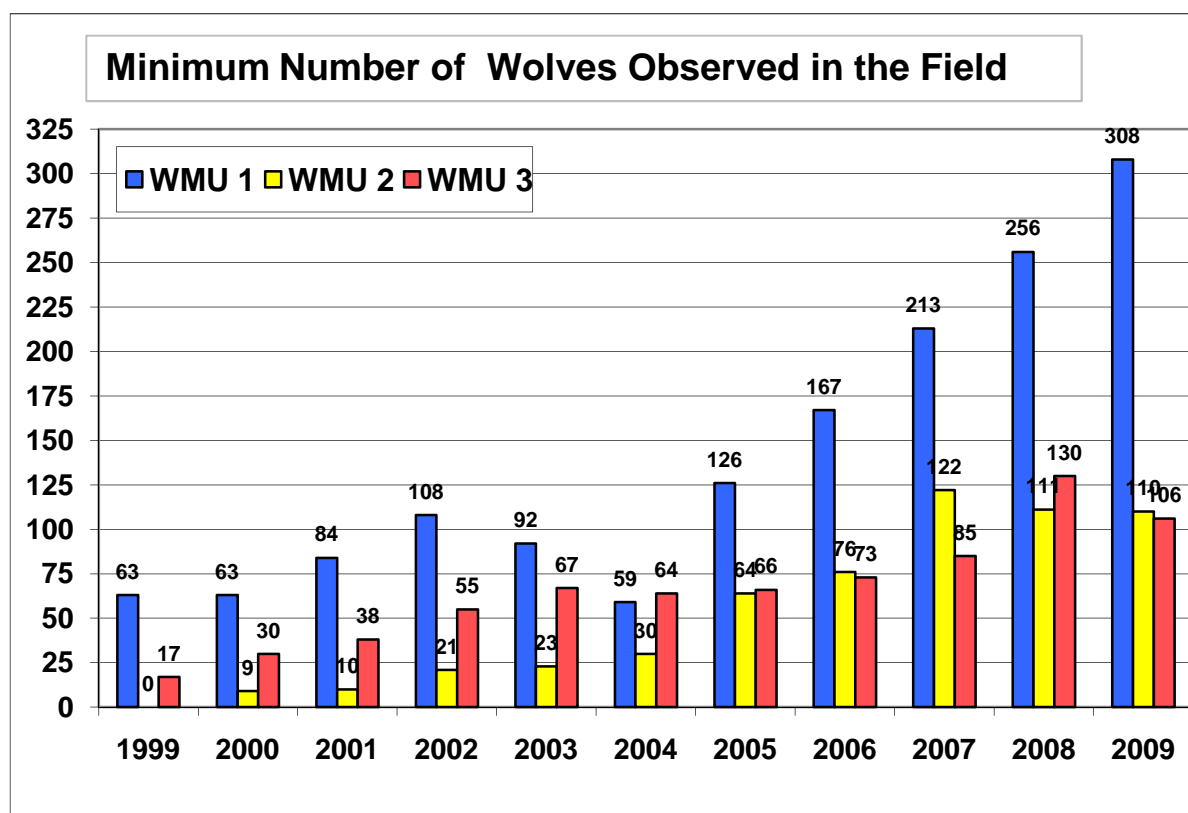
Figure 1. Ten year trend in the minimum number of wolves (top) and Breeding Pairs (bottom) in the 2009 Wolf Management Units, 1999-2009, through FWP's field-based monitoring efforts (Sime et al. 2010).

Total Documented Mortality, includes 2009 Harvest

Legend:
- WMU 1 total mort (blue)
- WMU 2 total mort (yellow)
- WMU 3 total mort (red)

Year	WMU 1	WMU 2	WMU 3
1999	14	0	9
2000	22	2	5
2001	7	0	10
2002	16	0	16
2003	5	0	28
2004	2	0	38
2005	12	9	32
2006	22	15	17
2007	29	30	37
2008	73	35	43
2009	127	82	45

Wolf Mortality due to Conflicts with Livestock, Agency Control Only

Legend:
- WMU 1 agency control (blue)
- WMU 2 agency control (yellow)
- WMU 3 agency control (red)

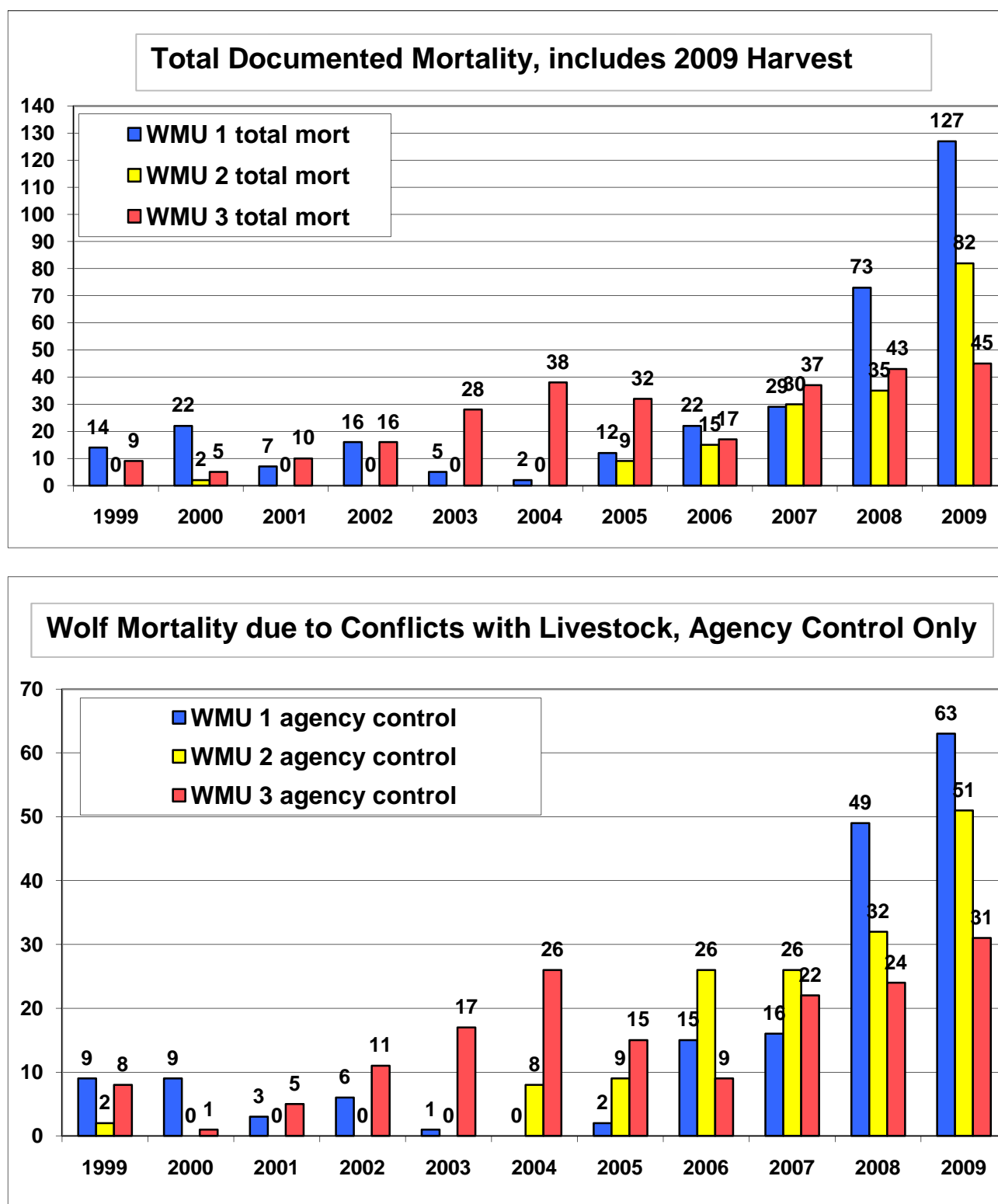| Year	WMU 1	WMU 2	WMU 3
1999	9	2	8
2000	9	0	1
2001	3	0	5
2002	6	0	11
2003	1	0	17
2004	0	8	26
2005	2	9	15
2006	15	26	9
2007	16	26	22
2008	49	32	24
2009	63	51	31

Figure 2. Ten year trend in the documented wolf mortality due to all causes (top) and agency control (bottom) in the 2009 Wolf Management Units, 1999-2009, through FWP's field-based monitoring efforts (Sime et al. 2010).

2. Simulate Effects of Harvest

Once the baseline wolf population dynamics are determined, the model determines the population that would theoretically be on the ground immediately before the season started. The model then subjects that population within each 2009 WMU to different rates of harvest. The model assumes that all harvest mortality is in addition to (i.e. additive) other mortality types and levels already accounted for by the model. The model then simulates how harvest might affect the minimum number of wolves and the number of BPs in the actual year of harvest. Predictions are made for each metric, representing plausible changes that can be expected in the status of the wolf population attributable to harvest.

Field-based measures of reproduction, immigration / emigration, and mortality in the actual year of harvest are not considered in the simulation exercise itself. However, they are assessed at the time quotas/ permit levels are set and finalized. This allows FWP to be more conservative when recommending tentative quotas in May of the year of harvest. Final quotas would be established in July immediately prior to a season which starts in mid-September in a limited number of backcountry areas. This allows current year's data to be incorporated into the decision process in case there are significant, unexpected developments (e.g. poor pup survival due to disease, increased mortality due to conflicts with livestock during 2010, or decreased mortality due to conflicts with livestock in 2010).

Quotas that would produce harvest rates from 20% to 50% in each 2009 WMU were simulated. The simulation included all possible combinations of these rates, at 5% increments, for a possible 280 combinations of harvest distributed across three 2009 WMUs. Each combination of harvest rates was simulated 1000 times. The minimum total number of wolves (includes lone dispersing animals) and BPs after one harvest season were estimated after each simulation run for each 2009 WMU and at the statewide level. The Lower and Upper 95% Confidence Intervals were also calculated for each one of the 1000 simulations. The average number of 1000 predictions of total wolves and BPs is calculated for each harvest rate combination. The average of 1000 predictions becomes "the" predicted outcome of that combination of harvest rates for the purposes of comparison and forecasting change in the population trajectory. The actual minimum and actual maximum values for Lower and Upper Confidence Intervals were selected to represent the widest possible degree of error and risk.

The harvest model simulations made the simplifying assumptions that:
- Wolf mortality due to public harvest is random and is additive to wolf dispersal and all other forms of mortality, including natural mortality, illegal wolf harvest, and mortality due to depredation in each area.
- Managers do not know the statewide number of BPs with 100% certainty; therefore the BP probability estimator was used to estimate the number of BPs for those packs lacking field observations to confirm BP status (Mitchell et al. 2008, Gude et al. 2009, Mitchell et al. 2010).
- Managers do not know the number of lone or dispersing wolves with certainty. Therefore, the raw model input consists of wolves known to be living in packs according to FWP's field monitoring efforts. The number of lone / dispersing wolves is then accounted for mathematically. According to the published literature, an estimated 10-15% of the wolf population occurs as lone individuals. Thus the total number of "pack-living" wolves predicted by the model needed to be adjusted upward by 10% to arrive at the predicted total wolf population. The model output consists of the "pack-living" wolves expanded by 10% to incorporate lone/dispersing individual wolves to predict the total number of wolves.

3. Simulation Results

The results of each combination of harvest rates were scrutinized to determine whether it resulted in a "risky" outcome in which number of BPs (the mean of 1000 simulation runs) went below 15. This threshold represents a boundary below which a harvest season in the following year would be cancelled, as dictated by the state management plan. By assuming that harvest would be additive to all other forms of mortality, and only considering "no risk" harvest scenarios, FWP is taking a conservative approach.

The simulations indicated that the Montana wolf population can support a harvest season in various combinations of rates in each of the three 2009 WMUs, given the population vital rates observed in 2008 - 2009. The simulations also indicated that harvest can initiate population declines within each WMU and at the statewide level. Generally speaking, progressively higher harvest rates resulted in progressively steeper population declines, although the relationship was not linear. This is because of baseline population differences between each of the three units (Mitchell et al. 2008) and other types and levels of wolf mortality unique to each 2009 WMU (see Figures 1 and 2).

The model predicted that progressively higher harvest rates in WMUs 2 and 3 would result in fewer wolves and BPs at the statewide level and especially in these two units, respectively. This suggests the level of harvest and how it is distributed across all three 2009 WMUs has implications for the individual unit and the statewide population. For example harvest rates in WMUs 2 and 3 approaching 30% are predicted to result in approximately 2 and 8 BPs, respectively in each unit. This is in contrast to a 30% harvest rate in WMU 1 that is predicted to result in approximately 17 BPs in that unit at the end of the year. This is because Montana's wolf population is not distributed equally across all three WMUs. WMU 1 has the highest 2009 minimum count (310 wolves) compared to WMU 2 (110 wolves) or WMU 3 (106) (see Sime et al. 2010 and Figures 1 and 2). Similar levels of harvest in each area should have different predicted outcomes, given the different minimum counts. Therefore, the model suggests careful consideration of the actual quota in each WMU and how the total statewide harvest quota is distributed across all WMUs. This is because of the interest to assure that the wolf population does not fall below 15 BPs and that adequate numbers of BPs are present in each WMU to assure connectivity.

4. Consider Combinations of Harvest Rates

Based on the 2008-2009 model simulations, almost all combinations of harvest rates out to 50% in each WMU resulted in a "no risk" outcome where the BP prediction did not drop below 15 at the statewide level. However, wolf population dynamics and current levels of human-caused mortality are different in each of the three management units (Mitchell et al. 2008). Therefore, various combinations of harvest rates may have yielded similar predicted statewide outcomes, but the distribution of the total number of wolves and BPs varies across WMUs, depending on the harvest rate for that unit. Nonetheless, these results suggested that harvest rates could vary within each of the proposed management units to legitimately reflect local social and biological factors (such as the status of wolf and/or prey populations, livestock damage, social tolerance, etc.) while still maintaining a secure population statewide and assuring connectivity within Montana and the northern Rockies wolf populations, respectively.

Quota scenarios were based on the minimum number of wolves that FWP knew were present on December 31 of the previous year. There will be more wolves present on the ground at the start of the current year's hunting season due to the current year's reproduction (April 2010 birth pulse) and

immigration adding to the population. Current year's mortality could be compared to the previous year to determine the ongoing validity of that model assumption. If mortality levels exceed previous year's levels, it can be accounted for at the time final quotas are set. Increasing population trends to date demonstrate that reproduction and immigration have exceeded emigration and total mortality. In this way, the model and quota-setting process is conservative -- it is based on known wolves plus an estimated 10% lone wolves not affiliated with a pack and can account for wolf mortality (and reproduction to some extent) through July when final quotas are set.

There is considerable variation in the level of human-caused mortality that a wolf population can withstand and remain relatively stable. Some studies are beginning to address the question of whether regulated public harvest mortality can compensate for other forms of mortality or whether harvest is always additive (i.e. if harvest mortality increases then mortality due to other causes decreases and is "off set" so the total mortality level stays about the same; alternatively, if harvest mortality will always be "in addition to" other forms of mortality). General rules of thumb are available in the published literature. Important factors include overall wolf density and population size, reproduction, immigration / emigration rates in the local Montana and regional northern Rockies population, road density, habitat, and other sources and levels of mortality (e.g. livestock-related), prey base, and livestock density (Fuller et al. 2003; Person and Russell 2007; Adams et al. 2008).

Depending on the desired goal or outcome, various combinations of harvest rates could be selected to facilitate a population increase, population stability, or a population decrease. Graphical results of a range of alternative scenarios are presented below. All results presented are based on current levels of FWP field monitoring effort.

How the Model Performed Relative to the 2009 Hunting Season and FWP Monitoring Efforts

As measured by FWP's field monitoring efforts, the 2009 Montana wolf population grew 4% from the 2008 year-end total minimum. This compares with an 18% increase from 2007 to 2008 and even higher rates in previous years. Thus the Montana wolf population growth rate is slowing down. Reasons for this reduction rate include increased total mortality, including public harvest and agency control (255 documented in 2009 vs. 151 in 2008) and a Montana landscape where the areas least prone to conflicts with livestock are already occupied by resident wolf packs. By applying the model in single year fashion, the model automatically incorporates changes in observed population trends -- albeit expressed as the minimum documented through field-based efforts.

Regardless of any potential modest disparity between what was predicted by the model and FWP's minimum observed counts for December 31, 2009, the modeling effort has been informative. The model provides a mechanism to compare alternative harvest scenarios and gauge risk using a mathematical approach grounded in the previous year's actual field data. The field monitoring data provide a mechanism to "ground truth" the model to identify faulty assumptions, to refine the model itself, or to learn more about how the wolf population responded to harvest or any other attributes in the model. Therefore, in the iterative process of adaptive harvest management and with one-year's experience, FWP can only now begin to bridge interpretation of what the model predicted with what is known about minimum observed counts obtained using field-based methods.

December 31 Minimum Counts from Field-Based Monitoring efforts
minimum total number of wolves, number of packs, number of breeding pairs

Population Model
Start with December 31 field-based minimum pack-living wolves

ADD wolves (10% for lone dispersers, birth, immigration)

SUBSTRACT wolves (emigration, death)

DETERMINE simulated population pre-hunt

Ongoing Field Monitoring Efforts

Harvest: September - December

Simulate Harvest 1000 times

SUBTRACT harvest mortality as a percent of the simulated population and harvest mortality is additive to other causes; model output is mean total wolf numbers, mean breeding pair, upper and lower 95% confidence intervals

Ongoing Field Monitoring Efforts

Birth Pulse: new litters born in Spring

Death = non-harvest causes

Study Simulation Results
Review combinations of harvest rates for management units and statewide; consider total predicted wolf numbers and number of pack-living wolves; assess risk

Select and Set Quotas
(as percent of simulated population after considering harvest model prediction results)

Tentative Recommendation: May

Final Adopted: July
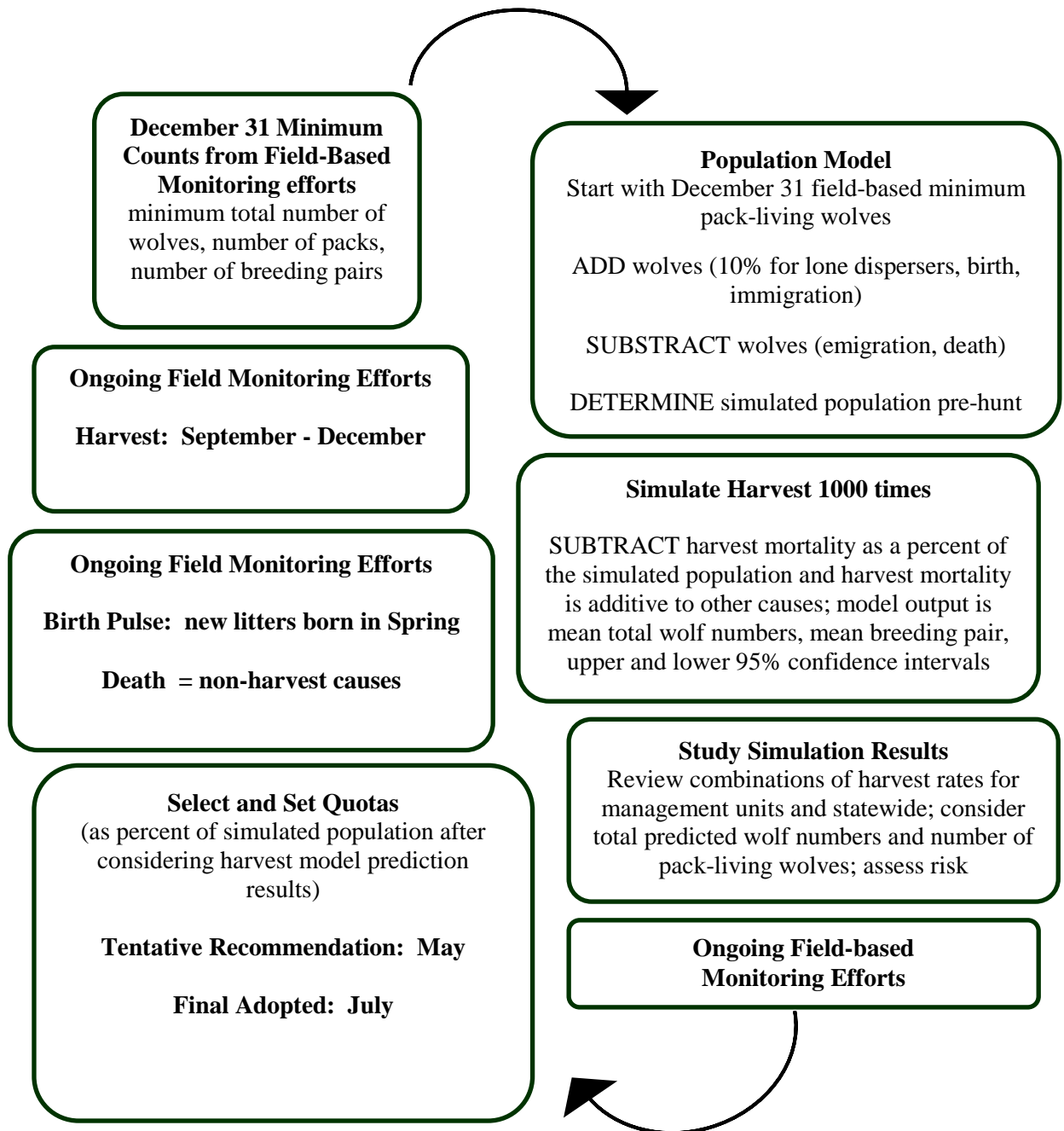
Ongoing Field-based Monitoring Efforts

Figure 3. A flow chart of a wolf harvest simulation model, field-based monitoring activities, and the quota setting process.
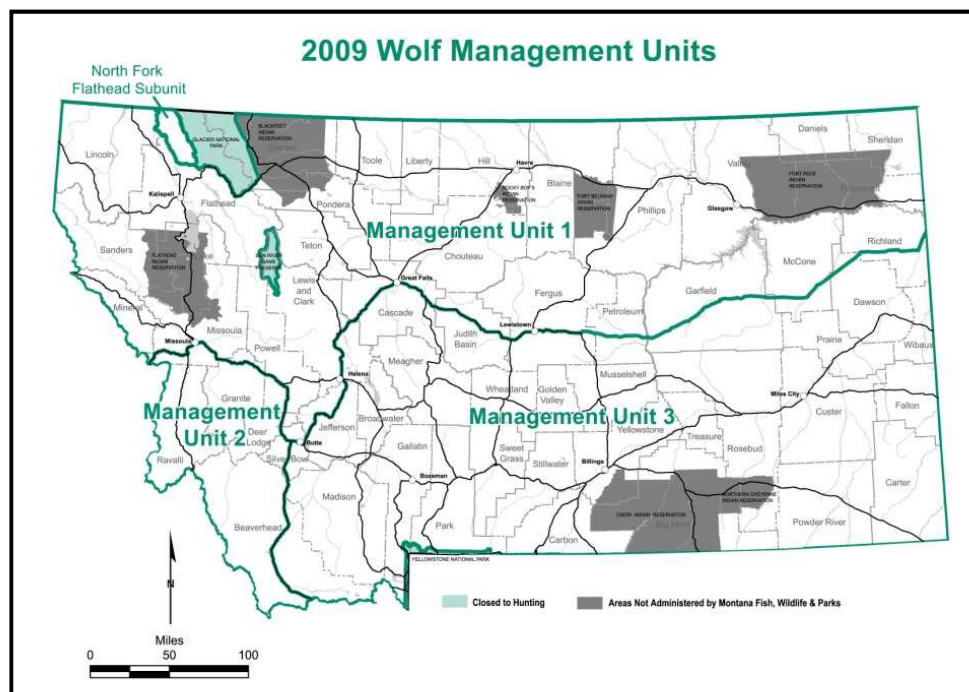
Figure 4. Three 2009 Wolf Management Units, and the North Fork Flathead Subunit. The 2010
wolf season proposal recommends creating smaller units within these broad areas
(Northwestern Montana – 2009 WMU 1, Western Montana – 2009 WMU 2, and
Southwest Montana – 2009 WMU 3), for a total of 14 units proposed statewide in 2010.

Results and Interpretations of the Predicted Outcomes of
Modeling Various Harvest Scenarios

Tabular Results

Given that the actual Montana statewide wolf population growth rate slowed down to 4% from 2008
to 2009 (much closer to zero than 18%), the 2010 model results will also reflect and assimilate
declining rates of population growth since the model begins with actual 2009 field-based data.

For the purposes of determining the rate of harvest associated with a particular quota, the model
first determines what the total population would be in *the absence of any harvest* using vital rates
and data obtained from field monitoring efforts. The 2010 model predicted a total population of
667 wolves (includes lone dispersing wolves) with no harvest whatsoever. The model's harvest rate
then is calculated to be the hypothetical quota divided by 667, multiplied by 100 to obtain a percent.

For the purposes of assessing risk that a combination of harvest rates (and associated quotas), FWP
compares the model's predicted number of BPs with 15BP as described previously. For the
purposes of determining whether the harvest levels initiate population decline, maintain stability, or
result in population increase from known 2009 minimum counts to predicted 2010 levels, FWP used
the following approach, based on comparison of the 2009 known number of pack-living wolves
with the predicted number of pack living wolves in 2010 (See Table 1):

1. Determine the total number of wolves the model predicted for the 2010 year end
2. Determine the predicted total number of pack-living wolves by multiplying the predicted total number of wolves by 0.90; based on the peer-reviewed literature, FWP estimates that about 10% of the total wolf population is comprised of lone dispersers.
3. Determine the percent change by comparing the 2010 predicted number of pack-living wolves with the 506 (known minimum number of wolves living in Montana packs at the end of 2009).

The model also predicts the number of BPs at the end of 2010. To determine the percent change in BPs from known at the end of 2009 to predicted at the end of 2010, the model prediction was compared with the minimum of 37BPs known at the end of 2009 (Sime et al. 2010). The reader will note that the percent decrease in the number of BPs is steeper than the percent declines shown for the number of pack-living wolves as the hypothetical statewide quota increases from 114 to 272. This is, in part due to the fact that higher quotas increase total wolf mortality in general, which in turn decreases individual pack sizes. Smaller packs have a lower probability of qualifying as a BP for a variety of reasons (see Mitchell et al. 2008). Through 2008, the average pack in Montana had about a 40% probability that it would qualify as a BP (a pack having an adult male, an adult female, and at least 2 pups survive to December 31). This is due to a variety of factors, including human-caused mortality. Therefore, it is prudent to consider the trajectory and magnitude of change in both pack-living wolves and the number of BPs comprehensively when considering the potential effects of harvest on the 2010 year end population.

Table 1. Predicted model outputs for a range of potential statewide quotas and the percent and direction of change for the 2010 model predictions when compared to known, minimum 2009 field-based data.

Potential 2010 Statewide Quota	Model Predicted 2010 Year End Total Wolves	Model Predicted 2010 Year End Total Pack-Living Wolves (assumes 10% of the total population is lone/dispersing)	Model Predicted 2010 Year End Total Breeding Pairs	Percent Change in Number of Pack-Living Wolves from 2009 Minimum Known to Predicted 2010 Year End (506 pack-living wolves on 12-31-09)	Percent Change in Total Number of BPs from 2009 to Predicted 2010 Year End (37 BPs on 12-31-09)
114	552	497 (552 x 0.90)	30	2% decrease	19% decrease
150	516	464 (516 x 0.90)	27	8% decrease	27% decrease
186	488	439 (488 x 0.90)	26	13% decrease	30% decrease
216	448	403 (448 x 0.90)	23	20% decrease	38% decrease
272	390	351 (390 x 0.90)	19	31% decrease	49% decrease

Graphical Results

The following pie charts illustrate various potential harvest levels statewide and in each of the three 2009 WMUs. The charts illustrate a potential statewide quota spread across individual WMUs, the predicted total number of wolves (includes lone dispersers) and predicted number of BPs statewide and within each 2009 WMU (Figures 5-9).

Figure 5. Statewide quota of 114, with individual quotas of 68, 21, and 25 respectively across all 2009 WMUs. The statewide harvest rate is about 17%. The model predicts about 552 total wolves (includes lone dispersers), 497 pack-living wolves, and 30 BPs at the end of 2010. These results suggest a 2% decline in the number of pack-living wolves and a 19% decline in BPs from minimum known through field-based efforts at the end of 2009 to predicted year end in 2010.

Statewide Quota = 114
Quota by 2009 WMU
(% harvest rate by WMU: 20, 20, 20)

Statewide Quota = 114
Predicted Total Number of Wolves
by 2009 WMU (552 total)

Statewide Quota = 114
Predicted Total Number of BPs
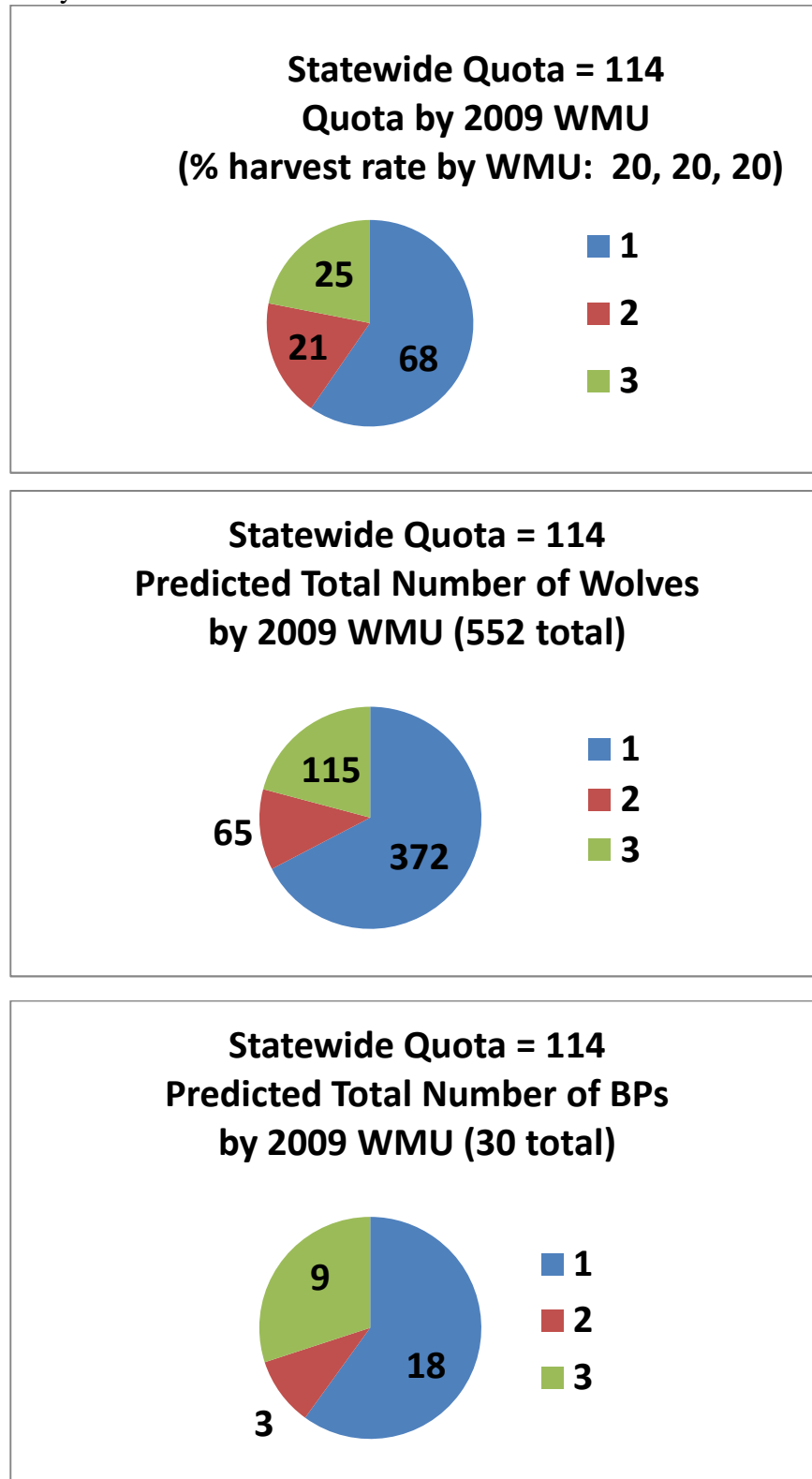**by 2009 WMU (30 total)**

Figure 6. Statewide quota of 150, with individual quotas of 68, 31, and 51 respectively across all 2009 WMUs. The statewide harvest rate is about 22%. The model predicts about 516 total wolves (includes lone dispersers), 464 pack-living wolves, and 27 BPs at the end of 2010. These results suggest an 8% decline in the number of pack-living wolves and a 27% decline in BPs from minimum known through field-based efforts at the end of 2009 to predicted year end in 2010.

Statewide Quota = 150
Quota by 2009 WMU
(% harvest rate by WMU: 20, 30, 40)

51 · 68 · 31 — 1, 2, 3

Statewide Quota = 150
Predicted Total Number of Wolves
by 2009 WMU (516 total)

89 · 55 · 372 — 1, 2, 3

Statewide Quota = 150
Predicted Total Number of BPs
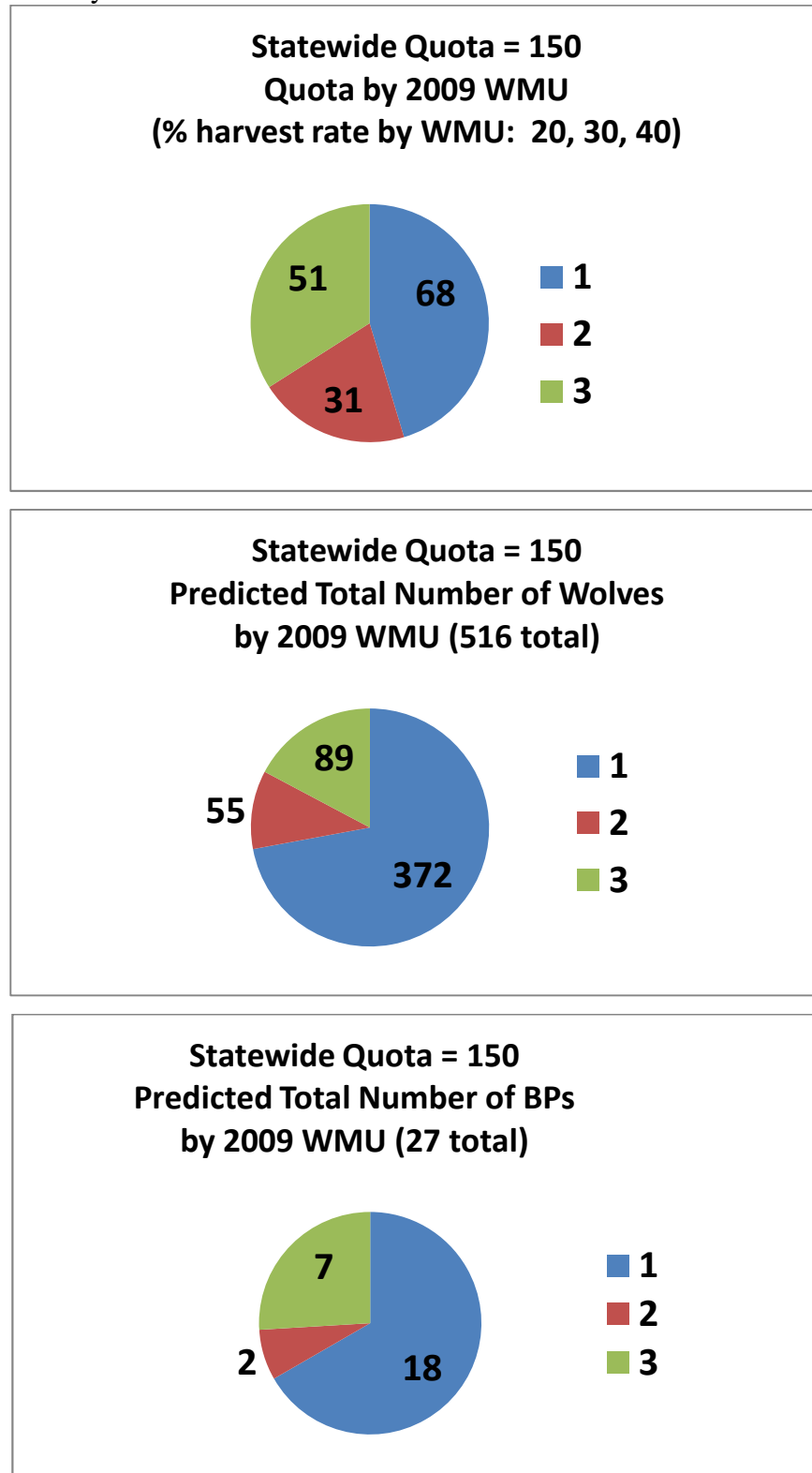**by 2009 WMU (27 total)**

7 · 2 · 18 — 1, 2, 3

Figure 7. Statewide quota of 186, with individual quotas of 122, 26, and 38 respectively across all 2009 WMUs. The statewide harvest rate is about 28%. The model predicts about 488 total wolves (includes lone dispersers), 439 pack-living wolves, and 26 BPs at the end of 2010. These results suggest a 13% decline in the number of pack-living wolves and a 30% decline in BPs from minimum known through field-based efforts at the end of 2009 to predicted year end in 2010.

Statewide Quota = 186
Quota by 2009 WMU
(% harvest rate by WMU: 35, 25, 30)

38 · 26 · 122 · 1 · 2 · 3

Statewide Quota = 186
Predicted Total Number of Wolves
by 2009 WMU (488 total)

100 · 60 · 328 · 1 · 2 · 3

Statewide Quota = 186
Predicted Total Number of BPs
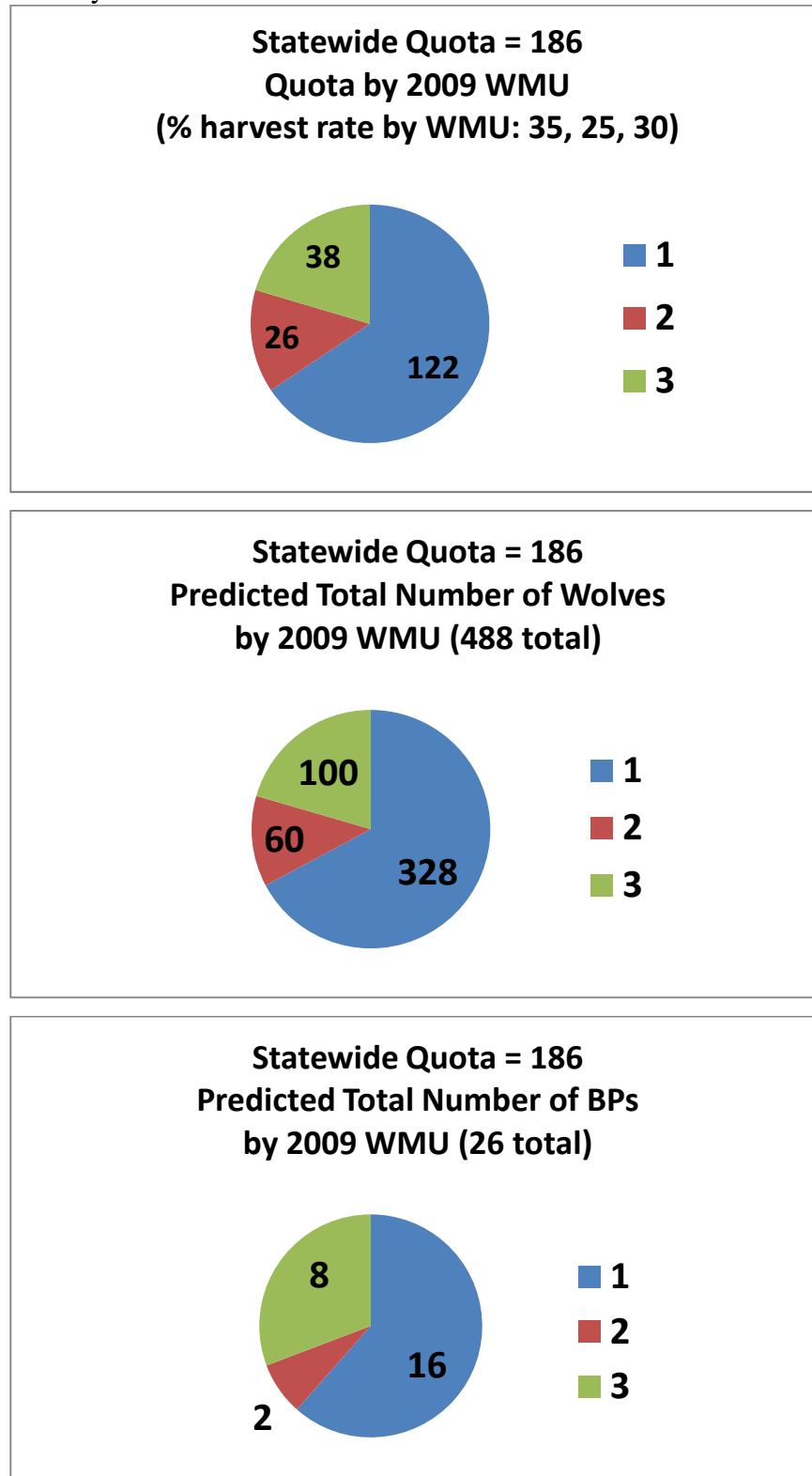**by 2009 WMU (26 total)**

8 · 16 · 2 · 1 · 2 · 3

Figure 8. Statewide quota of 216, with individual quotas of 133, 31, and 52 respectively across all 2009 WMUs. The statewide harvest rate is about 32%. The model predicts about 448 total wolves (includes lone dispersers), 403 pack-living wolves, and 23 BPs at the end of 2010. These results suggest a 20% decline in the number of pack-living wolves and a 38% decline in BPs from minimum known through field-based efforts at the end of 2009 to predicted year end in 2010.

Statewide Quota = 216
Quota by 2009 WMU
(% harvest rate by WMU: 40, 30, 40)

52 · 31 · 133 — 1, 2, 3

Statewide Quota = 216
Predicted Total Number of Wolves
by 2009 WMU (448 total)

91 · 55 · 302 — 1, 2, 3

Statewide Quota = 216
Predicted Total Number of BPs
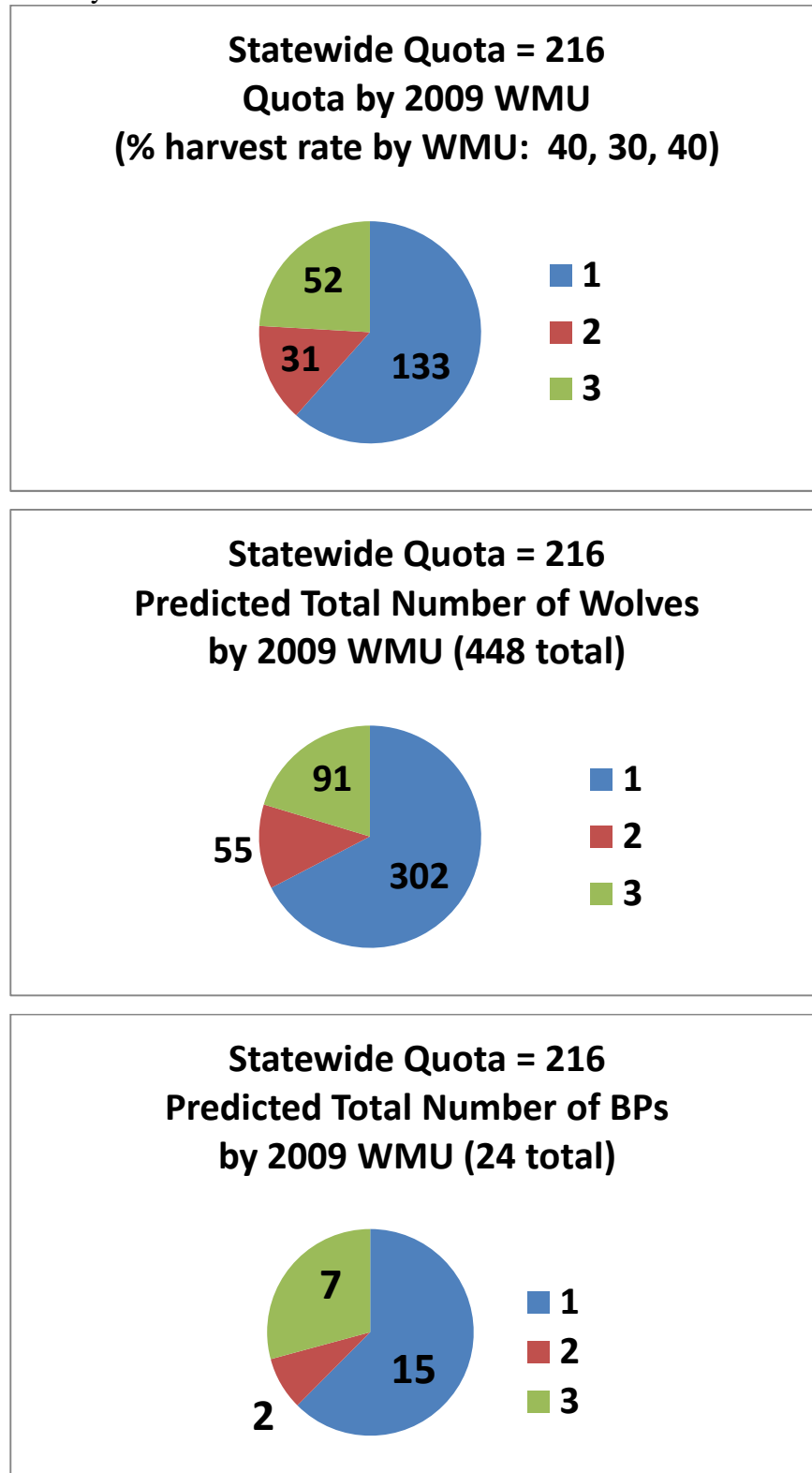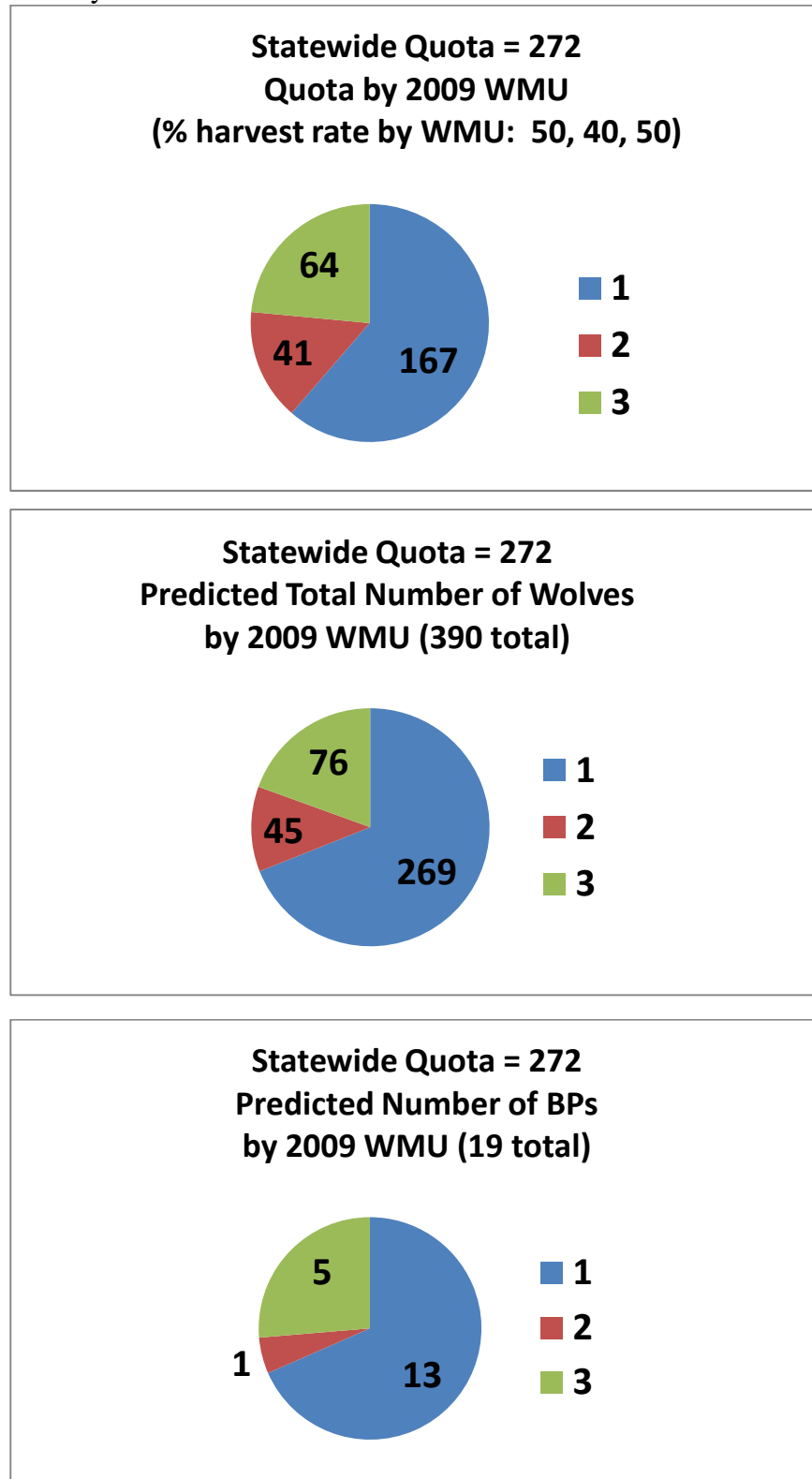**by 2009 WMU (24 total)**

7 · 2 · 15 — 1, 2, 3

Figure 9. Statewide quota of 272, with individual quotas of 167, 41, and 64 respectively across all 2009 WMUs. The statewide harvest rate is about 41%. The model predicts about 390 total wolves (includes lone dispersers), 351 pack-living wolves, and 19 BPs at the end of 2010. These results suggest a 31% decline in the number of pack-living wolves and a 49% decline in BPs from minimum known through field-based efforts at the end of 2009 to predicted year end in 2010.

Statewide Quota = 272
Quota by 2009 WMU
(% harvest rate by WMU: 50, 40, 50)

Statewide Quota = 272
Predicted Total Number of Wolves
by 2009 WMU (390 total)

Statewide Quota = 272
Predicted Number of BPs
by 2009 WMU (19 total)

References

Adams, L.G., R.O. Stephenson, B.W. Dale, R. T. Ahgook, and D. J. Demma. 2008. Population dynamics and harvest characteristics of wolves in the Central Brooks Range, Alaska. Wildlife Monographs 170.

Fritts, S.H., and L. N. Carbyn. 1995. Population viability, nature reserves, and the outlook for gray wolf conservation in North America. Restoration Ecology 3(1):26-38.

Fuller, T. K., L.D. Mech, and J.F. Cochrane. 2003. Wolf Population Dynamics. Pages 161-191 *in* L. D. Mech and L. Boitani, editors. Wolves: behavior, ecology, and conservation. The University of Chicago Press, Chicago, Illinois, USA.

Gude, J.A., M. S. Mitchell, D. E. Ausband, C. A. Sime, and E. E. Bangs. 2009. Internal validation of predictive logistic models for decision making in wildlife management. Wildlife Biology. 15:352-369.

Mitchell, M. S., D. E. Ausband, C. A. Sime, E. E. Bangs, J. A. Gude, M. D. Jiminez, C. M. Mack, T. J. Meier, M. S. Nadeau, and D. W. Smith. 2008. Estimation of self-sustaining packs of wolves in the U.S. northern Rocky Mountains. Journal of Wildlife Management 72:881-891.

Mitchell, M. S., J. A. Gude, D. E. Ausband, C. A. Sime, E. E. Bangs, M. D. Jimenez, C. M. Mack, T. J. Meier, and M. S. Nadeau. 2010. Test of an estimator for successful breeding pairs of wolves in the U.S. northern Rocky Mountains. Wildlife Biology, in press.

Person, D. K. and A. L. Russell. 2007. Correlates of mortality in an exploited wolf population. Journal of Wildlife Management 72(7):1540-1549.

Sime, C. A., V. Asher, L. Bradley, K. Laudon, N. Lance, M. Ross and J. Steuber. 2010. Montana gray wolf conservation and management 2009 annual report. Montana Fish, Wildlife & Parks. Helena, Montana. 173pp.

Smith, D. W, E. E. Bangs, J. K. Oakleaf, C. Mack, J. Fontaine, D. Boyd, M. Jimenez, D. H. Pletscher, C. C. Niemeyer, T. J. Meier, D.R. Stahler, J. Hoylan, V. J. Asher, and D. L. Murray. Survival of colonizing wolves in the northern Rocky Mountains of the United States, 1982-2004. Journal of Wildlife Management 74(4):620-634.

Prepared by: Carolyn Sime, Robin Russell, and Justin Gude, FWP; 5-5-10
Wolf Harvest Model Simulations Info Supplement FINAL for 5-13-10.pdf